REMARKS

Allowable Subject Matter

The Office Action states that claims 1-32 and 35-43 are allowable. The Patent Office Action has acknowledged that the prior art does not disclose in a method and apparatus for forming slotted tubular member having a plurality of slots by a seaming roller, a first detector for detecting a width of the slots to generate a width detection signal, a comparator for comparing the signal to a set value indicative of a desired end slot width to generate a correction signal and an adjustor connected to the comparator and seaming roller to vary a force applied by the roller to the plurality of slots in response to the correction signal. Applicants appreciate the Examiner's identification of allowable subject matter.

Supplemental Information Disclosure Statement

In compliance with the continuing duty under 37 CFR 1.56 to disclose information to the Examiner, Applicants respectfully submit Form PTO-1449 listing additional references of which Applicants have become aware.

Amendments to the Specification

Applicants have amended the Specification, at page 18, to identify the trade-mark "Lasiris." Further, Applicants have amended the Specification, at pages 11, 12, 19 and 20, to indicate that "Temposonics®" is the brand of magnetostrictive linear position sensors used by Applicants to control the hydraulic cylinder. Applicants submit that the term "tempsonic" is commonly used to refer generically to magnetostrictive linear position sensors which are useful for controlling hydraulic cylinders. A well known commercial brand of such sensors is "Temposonics®" (a registered trade mark of MTS® Systems Corporation, Minnesota, U.S.A., see brochure submitted herewith) which is used by Applicants.

Amendments to the Claims

This Amendment is in reply to the Office Action mailed on March 6, 2006. Claims 1-43 are pending in this application with entry of the present Amendment. Applicants have amended part (a) of independent claim 1 to recite to reduce the slot width "to a final slot width" to provide proper antecedent basis for claim 10. Support resides in the as-filed specification on page 9, line 20. Claims 11 and 12 are amended to recite "a hydraulic cylinder controlled by a magnetostrictive linear position sensor" to replace the trademark with the generic terminology.

Applicants believe that the amended claims better define the invention in a manner supported by the original application, and in a manner so as to render moot the rejections as set out below.

None of the amendments made herein constitutes the addition of new matter. Support for the amendments is found throughout the application and in the as-filed claims.

The Rejections under 35 U.S.C. §103

The Office Action rejects claim 33 as allegedly unpatentable over U.S. Patent No. 2,358,873 to Moss *et al.* in view of U.S. Patent No. 4,076,136 to Jenkin. Applicants respectfully traverse this rejection.

The Office Action states that:

> Moss discloses rollers (12, 22, 23) on supports (10, 16, 17) which are used to contact an outer surface of a rotating slotted tubular member (29) in order to seam slots (35) in the pipe. A downward force is applied by the seaming rollers (page 2, column 2, lines 8-10). Moss does not disclose that the force is maintained by an accumulator. Jenkin teaches (column 4, lines 34-39) that it is known to use an accumulator to absorb fluctuations in a position of rollers (12, 13) while maintaining a constant force applied to a pipe (15). The rollers are forced by hydraulic cylinders (30) connected to a common source of pressure. It would have been obvious to one skilled in the art at the time of invention to substitute the hydraulic force maintaining means as taught by Jenkin for the threaded means of Moss in order to maintain a specified seaming force on the rollers.

Applicants respectfully submit that a proper obviousness rejection has not been made. Section 706.02(j) of the USPTO Manual of Patent Examining Procedure states:

> To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine the reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art references (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art and not based on applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 493 (Fed. Circ. 1991).

Applicants respectfully submit that there is no motivation to combine any the cited references. Obviousness can only be established by combining or modifying the teachings of the prior art to produce the claimed invention where there is some teaching, suggestion, or motivation to do so found explicitly or implicitly in the references themselves or in the knowledge generally available to one of ordinary skill in the art. Even if one of ordinary skill in the art did consider the references chosen by the Examiner, the references themselves do not provide a suggestion of any success in combining the reference teachings to arrive at Applicants' claimed invention. Also even if combined, the references do not teach or suggest all of the features of the rejected claim.

The Office Action has combined the teachings of Moss *et al.* with those of Jenkin. Applicant submits that Moss *et al.* describes an apparatus for rolling the outer surface of a slotted pipe to partially close the slots as follows:

> The supports 10, 16 and 17 are then adjusted so as to apply the rollers with a desired force against the outer surface of the pipe. These supports are also adjusted in such a manner that the axes of the rollers 12, 22 and 23 will be disposed at somewhat of an angle with respect to the axis of the pipe 29. The pipe 29 is thereupon rotated and the rollers bearing against the outer surface thereof will upset the metal adjacent the slots which have been sawed and will

> narrow these slots. Due to the angular disposition of the rollers, the rollers and the frame in which they are carried will upon rotation of the pipe be moved longitudinally of the pipe so that the slots over the entire length of the pipe will be closed by substantially the same amount (page 2, column 2, lines 8-14).

Moss *et al.*'s method requires a pre-machined pipe which has been "milled and slotted with wide saws." Moss *et al.*'s method involves initially sawing the pipe to a wider gauge and then rolling the outer surface of the slotted pipe to partially close the slots. However, Moss *et al.* mentions that this method might require the further step of re-sawing the slots to obtain the desired gauge after closing; thus, the desired slot width is not initially or readily achieved.

As shown in Figure 2, the longitudinal slots of Moss *et al.* are oriented perpendicular to the longitudinal axis of the pipe. Such slots are thus parallel to the frame which moves in a longitudinal direction down the pipe. In comparison, as shown in Figure 1, Applicants' longitudinal slots are oriented parallel to the longitudinal axis of the pipe. Such slots are thus perpendicular to the seaming assembly. The seaming rollers are positioned to contact the outer surface of the slotted tubular member for <u>transverse movement across</u> the plurality of slots, as recited in Applicants' claim 33. No other orientation of slots in pipes is considered in Moss *et al.*

Nowhere does Moss *et al.* describe a mechanism to maintain the force applied by the seaming roller to the pipe. For this reason, one skilled in the art will recognize that the method of Moss *et al.* is limited to pipes which are close to round or perfectly round in order for the slots to be closed "by substantially the same amount" and to "exactly the gauge desired." In making the claimed invention, Applicants have considered that pipes tend to be out of round with a degree of surface roughness and that subsequently, a mechanism to maintain the force around the circumference of the pipe is advantageous. Moss *et al.* is clearly dealing with only pre-machined pipes having longitudinal slots oriented perpendicular to the longitudinal axis of the pipe. Even after the method of Moss *et al.* has been conducted, the further step of re-sawing

might be required to achieve the desired final slot width. Due to these shortcomings, one skilled in the art would not be motivated to turn to the teachings of Moss *et al.* to reduce slot width in pipes, particularly those out of round.

The Office Action turns to Jenkin for teachings of an accumulator. The additional cited reference does nothing to overcome the deficiencies of Moss *et al.*, nor is there a suggestion in either reference to combine the teachings of the two references. Applicants are concerned with the reduction of slot width in slotted pipes by using seaming. In contrast, Jenkin addresses an entirely different and unrelated problem, namely a method for straightening and spinning pipes while lining the inside of the pipe. Jenkin does not disclose any seaming roller for reducing slot width, nor does Jenkin teach any accumulator for maintaining the force applied by a seaming roller as the seaming roller moves across each of the plurality of slots, as recited in Applicants' claim 33. Rather, Jenkin's method provides collars to reduce the stress around the circumference of a pipe to avoid damage to the pipe:

> When the hydraulic pressure is increased to force the movable rollers 12 and 13 against the collars 35, the collars will distribute the stress around the wall of the pipe 15 and thereby avoid local high stresses in the pipe wall and preclude any possibility of damage or distortion to the pipe. The pressure exerted by the rollers 12 and 13 against the collars 35 will cause each collar to be urged centrally between the rollers 10 to 13 thus causing the pipe 15 to adopt a straight or more nearly straight form. The collars 35 are rotated by the rotary drive to the fixed rollers 10 and 11 and thus the pipe can be spun, for example to distribute the lining material (column 5, lines 51-62).

Jenkin clearly uses an accumulator for a different purpose, namely to force rollers against collars which straighten the pipe during spinning to achieve an even lining thickness within the pipe:

> If such a bowed pipe were to be rotated at high speed without straightening, the vibration would be excessive and an uneven lining thickness would result. To correct the non-straightness, the hydraulic pressure to the jacks 30 is increased, thus causing the movable rollers 13 and 12 to bear against the respective collar

> 35 and straighten the axis of the pipe 15. The pipe 15 is then spun at the required speed to distribute the lining for a predetermined time until the polyurethane is cured, the pressure exerted by the rollers 12 and 13 being maintained throughout this spinning time (column 6, lines 10-21).
>
> When the polyurethane has set, the spinning is stopped, the hydraulic pressure is switched off, and the collars are opened. The line pipe will, of course, then return to its relaxed, bowed condition again but will have a lining of approximately constant thickness and of constant internal diameter throughout its length (column 6, lines 26-31).

In making the present invention, Applicants recognized that application of an equal and constant force by the seaming rollers onto the pipe with an accumulator is greatly beneficial. Any vibration caused by the slots or an elliptical pipe will introduce pressure spikes, causing uneven slot width. For this reason, Applicants' method incorporates a seaming roller accumulator to reduce pressure pulsations caused by the movement of the seaming rollers over the slots in the pipe or caused by elliptical variations in the pipe. Moss *et al.* does not consider the problem of using pipes which are out of round. Jenkin does not teach or suggest the use of an accumulator for Applicants' intended purposes. Applicants submit that there is clearly no suggestion or motivation to modify any of the references or to combine the teachings of the references, since the combination does not teach or suggest the subject matter of Applicants' claim 33.

The fact that the references can be combined or modified is insufficient to establish *prima facie* obviousness. Combination of the references does not render the resultant combination as obvious, as the prior art does not suggest the desirability of the combination. Thus, Applicants submit that it is improper to reject any of these claims, or the claims dependent on these claims, under 35 U.S.C. §103(a) as a *prima facie* case of obviousness has not been established.

Furthermore, even if the references were combined, Applicants respectfully submit that a proper obviousness rejection has not been made since the further tests of *In re Vaeck,* 947 F.2d 488, 493 (Fed. Cir. 1991) have not been met:

> Where the claimed subject matter has been rejected as obvious in view of a combination of prior art references, a proper analysis under Section 103 requires, *inter alia*, consideration of two factors: (1) whether the prior art would have suggested to those of ordinary skill in the art that they should make the claimed composition or device, or carry out the claimed process; and (2) whether the prior art would also have revealed that in so making or carrying out, those of ordinary skill in the art would have a reasonable expectation of success. *See In re Dow Chemical Co.*, 837 F.2d 469, 473, 5 U.S.P.Q.2d 1529, 1531 (Fed. Cir. 1988). Both the suggestion and the reasonable expectation of success must be founded in the prior art, not in the Applicants' disclosure. *Id.*

Applicants respectfully submit that the prior art does not meet either criterion. As summarized above, none of the references teach or suggest Applicants' claimed subject matter. There would be no expectation of success in combining Moss *et al.* with Jenkin. The Office Action has selected Moss *et al.* as the primary reference upon which all 35 U.S.C. §103 rejections have been based. However, Applicants submit that one skilled in the art, looking for a solution to the problem of reducing slot width in pipes as addressed by Applicants' invention, would not look to Moss *et al.* or Jenkin for any solution.

Applicants have previously summarized the deficiencies of Moss *et al.* Briefly, Moss *et al.* provides a method which might not be conducive to pipes out of round or to slots having orientations other than perpendicular to the longitudinal axis of the pipe. The desired final slot width may not be readily achieved, necessitating an extra sawing step. Jenkin describes an accumulator for solving an entirely different problem. There would be no expectation of success in combining Moss *et al.* with Jenkin or modifying the reference teachings since none of the references has recognized that Applicants' particular method for reducing slot width in pipes would have the advantages described above (e.g., application to pipes out of round, achievement of even slot width in round

and elliptical pipes). Further, Applicants submit that neither Moss *et al.* nor Jenkin alone or in combination teach or suggest all the claim limitations.

Even if combined, the language of Applicants' claim 33 is not met. The references alone or in combination do not provide at least one seaming roller positioned to contact the outer surface of the slotted tubular member for <u>transverse movement</u> across the plurality of slots (see claim 33, part (a)). Further, the references alone or in combination do not teach <u>maintaining the force applied by at least one seaming roller</u> as the seaming roller moves across each of the plurality of slots <u>with an accumulator</u> (see claim 33, part (c)). Thus, the language of Applicants' claim 33 clearly distinguishes the teachings of Moss *et al.* and Jenkin. Reconsideration and withdrawal of this rejection of claim 33 are thus respectfully requested.

The Office Action rejects claim 34 as allegedly unpatentable over Moss *et al.* in view of U.S. Patent No. 4,312,207 to Przybyla *et al*. Applicants respectfully traverse this rejection.

The Office Action states that:

> Moss discloses rollers (12, 22, 23) on supports (10, 16, 17) which are used to contact an outer surface of a rotating slotted tubular member (29) in order to seam slots (35) in the pipe. A downward force is applied by the seaming rollers (page 2, column 2, lines 8-10). The rollers are moved longitudinally over the member as it is rotated. Moss does not disclose that the rollers are fixed in relation to a longitudinally moving and rotating pipe. Przybyla teaches that it is known to provide rollers that are fixed in relation to a moving pipe. The rollers are forced against the pipe by a piston rod (3) and slider (12) fixed on a support (1). It would have been obvious to one skilled in the art at the time of invention to fix the supports of Moss as taught by Przybyla in order to provide a stable rolling reaction force as the pipe is rotating.

Applicants respectfully submit that there is no motivation to combine the references. Also even if combined, the references do not teach or suggest all of the features of the rejected claim. The deficiencies of Moss *et al.* have been discussed above. In addition, Moss *et al.* does not teach or suggest longitudinally feeding and

axially rotating a pipe through at least one seaming roller, as recited in Applicants' claim 34. Rather, the pipe in Moss *et al.* is mounted in a lathe and the frame shown in Figure 2 is secured around the pipe. A roller is connected to the frame and Moss *et al.* states that the roller "engages the inside surface of one of the lathe ways 33 or 34, or some other surface along which it may move in a longitudinal direction" (page 2, column 2, lines 1-7). The pipe does not appear to be <u>fed</u> longitudinally through the seaming roller, as recited in Applicants' claim 34.

The Office Action turns to Przybyla *et al.* for teachings of rollers that are fixed in relation to a moving pipe. The additional cited reference does nothing to overcome the deficiencies of Moss *et al.*, nor is there a suggestion in either reference to combine the references. Applicants submit that Przybyla *et al.* addresses an entirely different problem. Przybyla *et al.* relates to a rolling mill for forming cross ribs on a pipe. The rolling mill is designed to facilitate tool attachment and exchange. Applicants' claim 34 explicitly recites "longitudinally feeding and axially rotating the slotted tubular member through the at least one <u>seaming roller</u>." However, Przybyla *et al.* does not provide <u>any</u> seaming rollers, but rather tools, in the form of packs of shaped discs, which are compressed from three sides against the pipe by actuators. Together with rotation of the tools, this pressure forms cross ribs in the pipe. The tools are in no way "fixed in relation to a moving pipe" as commented by the Office Action. Rather, the tools are attached to and guided by a moveable internal cylinder towards the pipe during formation of the cross ribs:

> When forming a periodic rib configuration, the piston 4 is hydraulically shifted to its extreme top position to leave a portion of a pipe being unribbed. After a preset time, the piston 4 returns to its former position due to adequate variation of pressure in the hydraulic system. During the travel of the piston 4 and piston rod 3, the slider 12 with internal cylinder 7 and yoke 15 with tool 16 are also moving, the steadiness of tool attachment being maintained (column 3, lines 24-27).

The tools can be moved away from the pipe "such that the internal cylinder 7 is being further shifted upwards, and thereby the slider 12 together with yoke 15. This displacement should be in the range of 20 mm to be sufficient to stop contacting the rolling discs with a formed rib" (column 3, lines 39-44). Applicants submit that there is clearly no suggestion or motivation to modify any of the references or to combine the reference teachings, since the combination does not teach or suggest the subject matter of Applicants' claim 34.

Even if the references were combined, Applicants respectfully submit that a proper obviousness rejection has not been made. None of the references teach or suggest Applicants' claimed subject matter. There would be no expectation of success in combining Moss *et al.* with Przybyla *et al.* The Office Action states that it would have been obvious to one skilled in the art at the time of invention to fix the supports of Moss *et al.* as taught by Przybyla *et al.* in order to provide a stable rolling reaction force as the pipe is rotating. Applicants respectfully disagree. Applicants note that by "support (1)," the Office Action is referring to the body of the mill housing upon which the actuators are simply mounted. The "supports" in Moss *et al.* are represented by the shafts or supports 10, 16 and 17 which are described as being "locked in position" within the frame shown in Figure 1. If such supports were fixed (i.e., if the frame were not moving in a longitudinal direction down the pipe) as suggested by the Office Action, Moss *et al.* nevertheless lacks a mechanism for feeding and rotating the pipe through the seaming rollers. No feeding or rotating mechanism is described in Przybyla *et al.* In contrast, Applicants' invention includes a head stock assembly for <u>feeding and rotating</u> a pipe through the subsequent clamp roller and <u>seaming roller</u> assemblies (see Figures 2-4). Applicants submit that neither Moss *et al.* nor Przybyla *et al.* alone or in combination teach or suggest all the claim limitations.

Even if combined, the language of Applicants' claim 34 is not met. The references alone or in combination do not provide at least one seaming roller positioned

to contact the outer surface of the slotted tubular member for transverse movement across the plurality of slots (see claim 34, part (a)). Further, the references alone or in combination do not teach longitudinally feeding and axially rotating the slotted tubular member through at least one seaming roller (see claim 34, part (c)). Thus, the language of Applicants' claim 34 clearly distinguishes the teachings of Moss *et al.* and Przybyla *et al.* Reconsideration and withdrawal of this rejection of claim 34 are thus respectfully requested.

In summary, none of the cited references taken alone or in combination renders obvious any of the claims of the present application. No combination of the prior art is warranted since the references themselves do not suggest of a proper combination. Even if a *prima facie* case of obviousness exists (which Applicants argue does not exist), the references in combination do not equate to the features of Applicants' claims. Withdrawal of all claim rejections is respectfully requested.

Conclusion

In view of the foregoing, it is submitted that this case is in condition for allowance, and passage to issuance is respectfully requested.

If there are any outstanding issues related to patentability, the courtesy of a telephone interview is requested, and the Examiner is invited to call to arrange a mutually convenient time.

This response is accompanied by a Petition for Extension of Time (one month) and a Supplemental Information Disclosure Statement. The Patent Office is authorized to charge $120.00 as required by 37 C.F.R. 1.17(a) and $180.00 as required by 37 C.F.R. 1.17(P), FOR A TOTAL OF $300.00, to Deposit Account No. 07-1969. It is believed that this response does not necessitate the payment of any additional fees

under 37 C.F.R. 1.16-1.17. However, if the amount authorized is incorrect, however, please the necessary fee to Deposit Account No. 07-1969.

Respectfully submitted,

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dmf:06Jul06

Temposonics®

Magnetostrictive Linear-Position Sensors

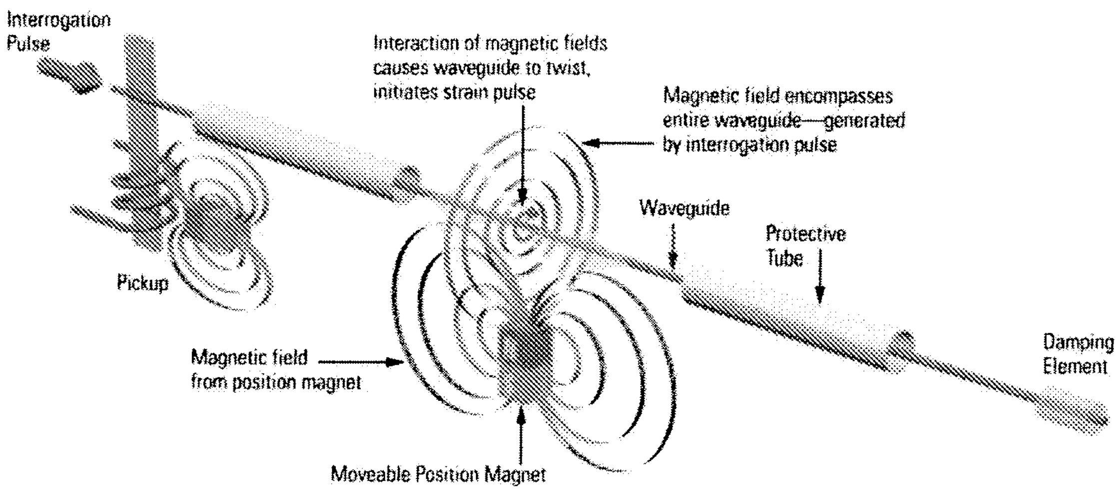
Appl. No. 10/825,959
Amendment dated 07/06/2006
Reply to Office Action of
03/06/2006
EXHIBIT A

MTS® SENSORS

550947 A

Magnetostriction, How it Works

Technical Paper



Magnetostrictive Principle

Introduction

Sensors based upon magnetostriction have been used in a wide variety of industrial applications for over 25 years since their invention at a company called Temposonics in the 1970's. The sensor's unique properties enable sensors to be built with measuring lengths from 1 cm to over 10 meters, with an accuracy on the order of microns. Over 1 million are in use today in industrial applications ranging from saw mills, injection molding and casting to petrochemical and pharmaceutical level control to off-road construction and agricultural machine control (see Figure 1).

Recently, the cost of this type of sensor has been reduced through automation, which has allowed its deployment in higher volume, lower cost commercial and light industrial applications such as medical instruments, tools, and recreational equipment. The new product based upon this reduction, called the C-Series sensor, is modular in nature.

The C-Series common core is a plastic housed sensor (see Figure 2) offered in short strokes up to 250 mm. Other modular housings (see Figure 3), and accessories in Figure 4) allow the customer to pick and choose the final assembly that matches their application's

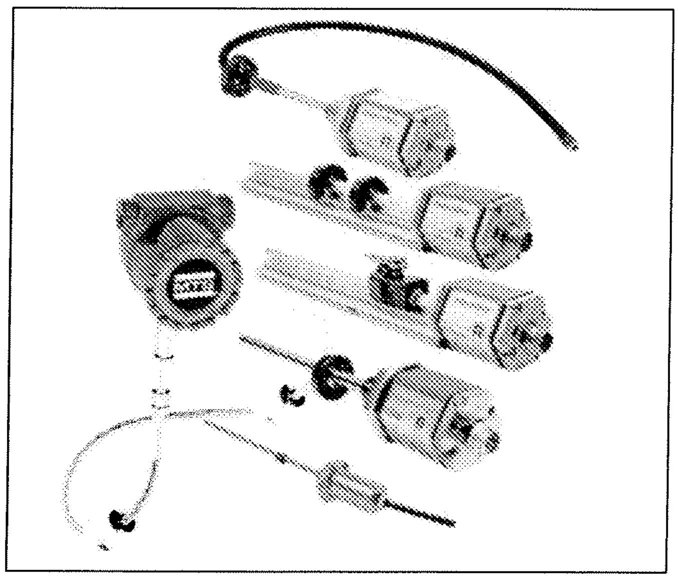
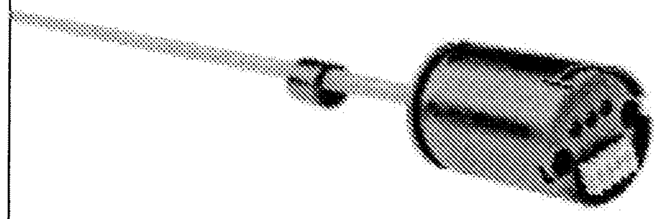


Figure 1: *The range of magnetostrictive sensors has grown considerably since their invention in the 1970's.*

Figure 2: *C-Series sensor magnetostrictive core sensor. Recent advantages in manufacturing techniques has allowed Magnetostrictive technology to be applied to a broad range of commercial and light industrial applications such as professional tools, medical equipment and recreational equipment.*



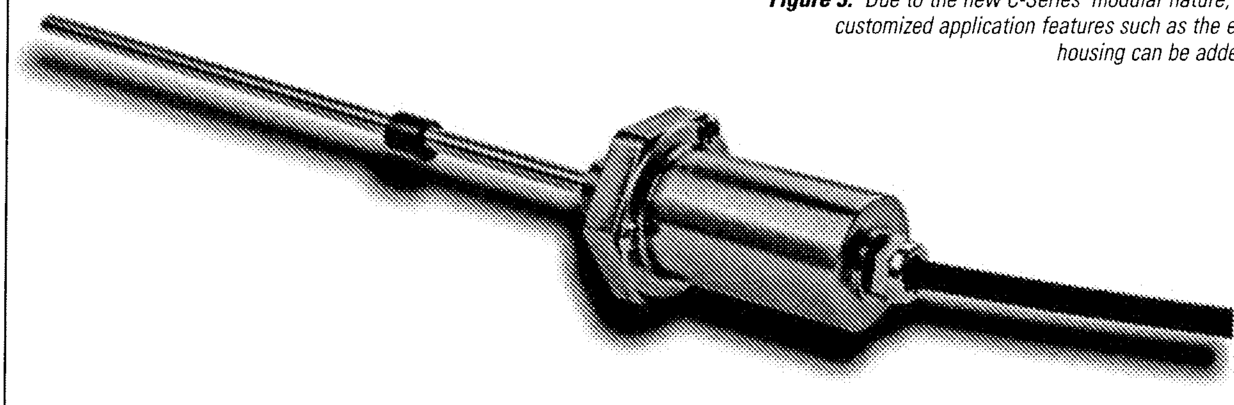


Figure 3: *Due to the new C-Series' modular nature, standard and customized application features such as the environmental housing can be added as options.*

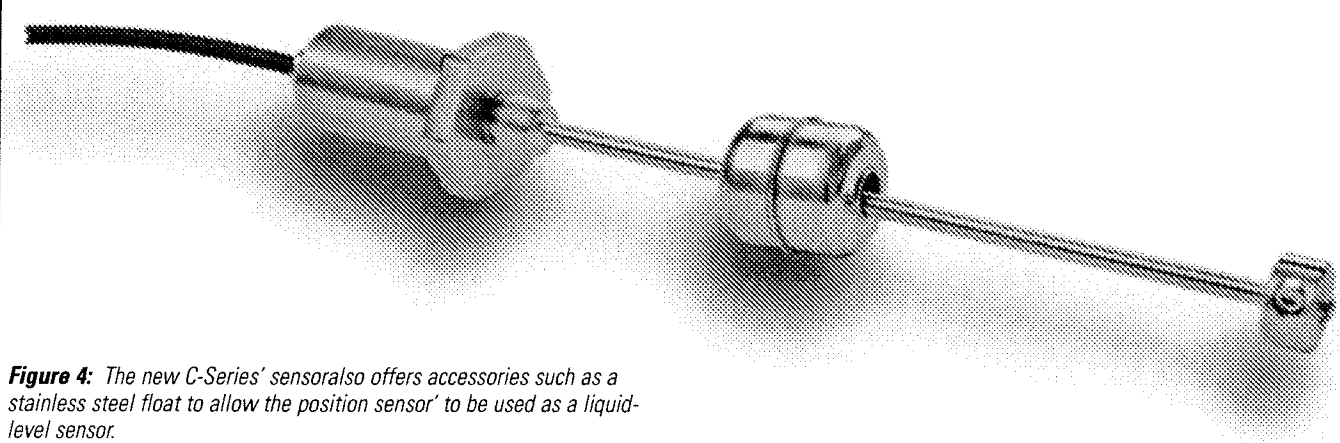


Figure 4: *The new C-Series' sensoralso offers accessories such as a stainless steel float to allow the position sensor' to be used as a liquid-level sensor.*

What is magnetostriction?

Magnetostriction is a property of ferromagnetic materials such as iron, nickel, and cobalt to change size and/or shape when placed in a magnetic field.

This physical response of a ferromagnetic material is due to the presence of magnetic movements, essentially a collection of tiny permanent magnets, or domains (see Figure 5). Each domain consists of many atoms. When a material is not magnetized, the domains are randomly arranged. When the material is magnetized, the domains are oriented with their axes approximately parallel to one another and the change in size or shape is made. Interaction of an external magnetic field with the domains also causes the magnetostrictive effect. The order of the domains, and thus the magnitude of the effect, can be influenced by alloy selection, thermal annealing, cold working, and magnetic field strength.

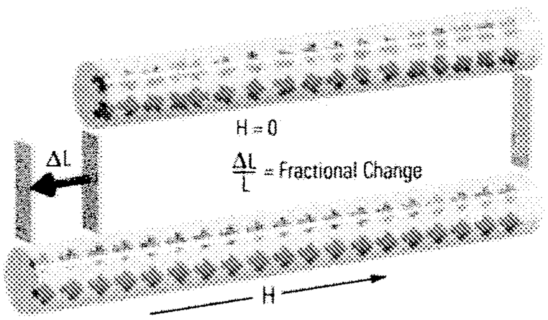


Figure 5: *Magnetic domains align in ferromagnetic materials when exposed to a magnetic field, causing a dimensional change.*

Ferromagnetic materials used in magnetostrictive position sensors are transition metals such as iron, nickel, and cobalt. In these metals, the 3rd electron shell is not completely filled, which allows the formation of a magnetic moment. (i.e., the shells closer to the nucleus than the 3d shell are complete, and they do not contribute to the magnetic moment). As electron spins are rotated by a magnetic field, coupling between the electron spin and electron orbit causes electron energies to change. The crystal then strains so that electrons at the surface can relax to states of lower energy. When a material has positive magnetostriction, it enlarges when placed in a magnetic field; with negative magnetostriction, the material shrinks.

Applying a magnetic field causes stress that changes the physical properties of a magnetostrictive material. However, the reverse is also true: applying stress to a magnetostrictive material changes its magnetic properties (e.g., magnetic permeability). That is, a dimensional change in the material can lead to induced magnetic fields. Magnetostrictive sensors (see Figure 6) employ both properties to generate an ultrasonic strain wave from the location of an external marker magnet and detect its passage by a fixed reference point in a wave guide. By knowing the speed of sound in the material, marker magnet position can be determined using a time-of-flight measurement technique.

As illustrated in Figure 6, the first step in the time-of-flight measurement is to apply an orthogonal magnetic field to a

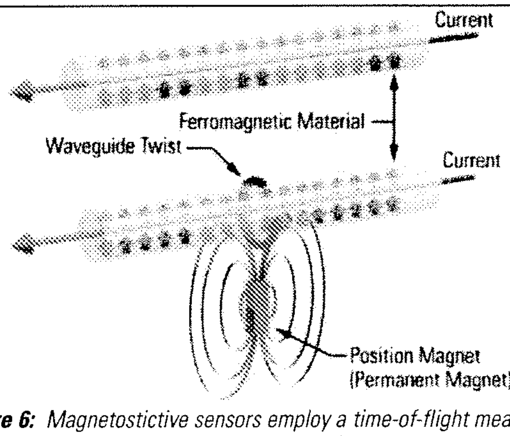


Figure 6: *Magnetostictive sensors employ a time-of-flight measurement technique by launching a strain pulse from the moving magnet position that travels at the speed of sound in the Magnetostrictive wire until it is detected by a pickup.*

magnetostrictive wire, and then pass a current through the wire. The Magnetostrictive effect causes a twisting at the location of the orthogonal magnetic field. The twisting is caused by interaction of the orthogonal magnetic field, usually from a permanent marker magnet, with the magnetic field along the magnetostrictive wire, which is present due to the current in the wire.

Because the current is applied as a pulse, the mechanical twisting travels in the wire as an ultrasonic wave. The magnetostrictive wire is therefore called the waveguide. Each magnetostrictive strain wave travels at the speed of sound in the waveguide material, approximately at 3000 m/s. The position magnet is attached to whatever is being measured, perhaps a piston in a cylinder. The waveguide wire is enclosed within a protective cover and is attached to the stationary part of the machine, perhaps a cylinder body.

the location of the position magnet is determined by starting a counter timer when the current pulse is launched. The current pulse causes a sonic wave to be generated at the location of the position
magnet. The sonic wave travels along the waveguide until it is detected by the pickup.

A pickup makes use of the reverse magnetostrictive effect described earlier. A small piece of magnetostrictive material, called the tape, is welded to the waveguide near one end of the waveguide. This tape passes through a coil and is magnetized by a small permanent magnet called the bias magnet. When a sonic wave propagates down the waveguide and then down the tape, the stress induced by the wave causes a permeability change in the tape. This in turn causes a change in the tape magnetic flux density, and thus a voltage output pulse is produced from the coil.

At a defined output level of the coil output voltage, the counter timer is instructed to stop. The elapsed time indicated by the timer then represents the distance between the position magnet and the pickup. The frequency of the counter determines the resolution of the measurement; the higher the frequency, the finer the resolution.

Elapsed time information is conditioned into the desired output. Many outputs are available such as DC voltage, pulse width modulation, start-stop digital pulses, CANbus, Profibus, Serial Synchronous Interface (SSI), HART, and various other smart sensor protocols, including custom units.

Today magnetostrictive sensors are used by many industries these sensors dominate approximately 10% of the entire long-linear sensors market. Traditionally, these sensors have been used in a vast range of manufacturing equipment including injection molding machines, wood processing equipment, hydraulic cylinders, hundreds of specialty manufacturing machines, process level control in pharmaceuticals and petrochemical plants, off and on-road machinery for construction and agriculture as well as many others.

Magnetostrictive linear position sensors are well regarded for ruggedness and accuracy. Pavement machines, off-road machinery and saw mill machinery provide some of the most demanding environments and the sensors perform reliably. Some applications, such as high end injection molding machines, require micron-level resolutions. Recent advances in magnetostrictive electronics, including counter timers that have 150 picosecond periods or better, allow this depth of performance.

New, novel automated manufacturing processes reduce unit cost on some new models into a whole new realm compatible with the cost demands of high volume products. This technology advancement, which offers high reliability and high performance, is suddenly very attractive for high-volume use in medical, recreational, professional tool and other extremely cost sensitive commercial or light industrial applications. Standard products are

Benefits

The magnetostrictive sensor is an absolute positioning device. A magnetostrictive sensor's electronic circuit measures directly, without any conversion, the interval of the sound wave's travel from the location of the magnet to the tip of the sensor. Resolution is limited only by practical factors (and by the electronic circuit) rather than by the measuring principle. In fact, in the standard industrial application (linear displacement) the accuracy of the magnetostrictive sensors are on the order of 1 to 2 microns (10-6 mm).

- Measurement is non-contact
- Complete integration is possible
- No wear parts
- Well-proven, long term stability
- High accuracy
- High temperature stability

A Magnetostrictive history

First discovered by Matteucci and Joule (1847) and extensively studied by Villari (1865) and Wiedemann, the application of Magnetoelasticity in Magnetostriction started during World War II in some sonar applications.

But many years intervened before finding the first industrial application. The first magnetostrictive linear position sensor was invented by Jacob Tellerman in 1975. He was developing delay lines for use in computer memory devices when it occurred to him to use similar technology to produce a position sensor. Tellerman had the idea of generating an ultrasonic wave at a varying location along the waveguide by using a permanent magnet. See Figure 7. Then the time elapsed until the ultrasonic pulse reached one end of the waveguide would indicate the position of the magnet. A new industrial sensor was born: he co-founded a company called Temposonics, which was further developed after being acquired in 1987 by MTS Systems Corporation.

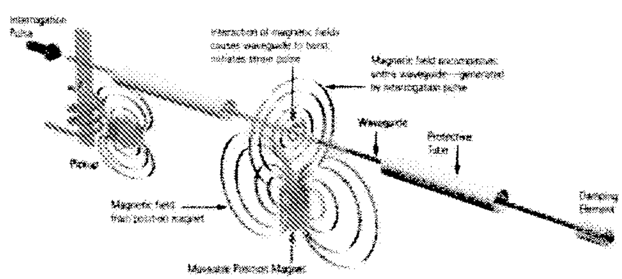


Figure 7: *The Magnetostrictive Sensor*

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